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Kaon loops in pion photoproduction: Facts and fancy

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Abstract

We show that a recent claim of huge kaon loop corrections to the electric dipole amplitude in neutral pion photoprodcution at threshold is incorrect. The difference between the two and three flavor chiral perturbation theory calculation is marginal and thus previous claims of a good understanding of this reaction remain valid.

In a recent paper, Banerjee and Milana [1] claim that there are huge kaon loop corrections to the electric dipole amplitude E_{0+} for neutral pion photoproduction at threshold. If that were true, all previous calculations of Bernard et al. should be considered incomplete and the reaction $\gamma p \to \pi^0 p$ could not be used to test the chiral dynamics of QCD (for a review, see [2]). While there are still some open questions concerning the convergence in the two–flavor case, the recent analysis of the new TAPS and SAL data does indeed lend credit to the approach and its extension to pion electroproduction [3, 4]. As spelled out in detail in Ref.[5], in the threshold region one has to consider two basic Feynman graphs, the so–called triangle and rescattering diagrams (plus their crossed partners). Evaluating these correctly with intermediate Λ, Σ^0 states, one finds the following kaon loop contribution for $\gamma p \to \pi^0 p$ at order q^3 in the chiral counting :

$$E_{0+}^{q^3,K}(\omega) = \frac{e\,F}{64\pi^2 F_\pi^3}\left(M_K^2 \,\arcsin\frac{\omega}{M_K} - \omega\,\sqrt{M_K^2-\omega^2}\right)\,, \tag{1}$$

with ω the pion energy in the πN cms frame and all other quantities are standard. We point out, however, that we could have used here $F_K = 1.2 F_\pi$ as well. This would reduce this contribution considerably. The difference to the result in [1] is the factor in front of the square root in Eq.(1). This can be traced back to the fact that Eq.(13) in [1] has the wrong sign, see e.g. ref.[5]. A detailed account of the SU(3) extension of the

work by Bernard et al. for SU(2) is given in Ref.[6]. With $F = 0.5$, $F_\pi = 93\,\mathrm{MeV}$, $e^2/4\pi = 1/136.037$ and $M_K = 495$ MeV, one has at threshold

$$E_{0+}^{q^3,K}(\omega = M_{\pi^0}) = 0.14 \cdot 10^{-3}/M_{\pi^+} \quad , \tag{2}$$

which is well within the theoretical uncertainty of the SU(2) calculation and can be accounted for by minor adjustments of the low energy constants a_3 and a_4, see [4, 5]. That the same holds for the neutron amplitude does not need to be elaborated on here. It is important to stress that in the SU(2) calculation with a fixed, non-zero strange quark mass, the kaons are frozen and can only contribute at order M_π^3. To be precise, one finds

$$E_{0+}^{q^3,K}(\omega = M_{\pi^0}) = \frac{e\,F\,M_\pi^3}{96\pi^2 F_\pi^3\,M_K} \tag{3}$$

which leads to almost the same result as in Eq.(2). Note that Eq.(14) given in [1] in the limit of fixed strange quark mass violates even the current algebra result for E_{0+} at $\mathcal{O}(M_\pi)$.

Finally, we would like to point out that the importance of measuring the electric dipole amplitude for the neutron has already been lucidly discussed in the 1992 paper by Bernard et al. [7] and stressed again in [5]. The reason to measure this quantity is to get a handle on possible isospin violations in the pion–nucleon system and not because of the suppression of kaon loop effects in the difference $E_{0+}^{\pi^0 p} - E_{0+}^{\pi^0 n}$ as claimed by Banerjee and Milana.

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